

AMENDMENTS TO THE CLAIMS

Please amend the claims as follows. This listing of claims will replace all prior versions and listings of claims in the application.

1. (Currently Amended) A method for fabricating a liquid containing ~~intermixed nanoparticulate~~ elements of groups IB and IIIA and optionally VIA, comprising ~~the steps of:~~ forming elemental non-oxide metal nanoparticles containing elements from group IB; and ~~forming elemental non-oxide metal nanoparticles from group IIIA; and~~ ~~providing a suspension comprised of one or more liquid metals, wherein the one or more liquid metals comprises at least one group IIIA based material;~~ optionally forming elemental non-oxide nanoparticles from group VIA; intermixing the elemental non-oxide nanoparticles from groups IB ~~and IIIA;~~ and optionally VIA, ~~with the suspension to form an ink;~~ wherein the ~~nanoparticles~~ are in a desired particle size range of between about 0.1 nm and about 500 nm in diameter, wherein, ~~for each element metal,~~ a majority of the mass of the ~~elemental metal~~-nanoparticles range in size from no more than about 40% above or below an average particle size, or, if the average particle size is less than about 5 nanometers, from no more than about 2 nanometers above or below the average particle size~~, and~~ ~~mixing the particles to form a liquid that serves as an ink.~~
2. (Original) The method of claim 1 wherein the group IB element is copper (Cu), the group IIIA element is indium and optionally includes gallium) and the group VIA element is selenium (Se) or sulfur (S) and a stoichiometric ratio of the Cu, In and Se or S in the liquid is approximately $CuIn_{1-x}Ga_x(S \text{ or } Se)_2$, where x is between 0 and 1.
3. (Original) The method of claim 1 further comprising coating the elemental non-oxide metal nanoparticles with a surfactant or polymer.
4. (Original) The method of claim 1 wherein forming the elemental non-oxide metal nanoparticles includes condensing a metal vapor.
5. (Canceled).

6. (Original) The method of claim 3 wherein forming the elemental non-oxide metal nanoparticles includes laser ablation, mechanical milling, grinding, nucleation from vapor, exploding wires by electrical current surge, thermal decomposition of organometallic compounds, sonolysis, pulse radiolysis, electrochemical reduction or chemical reduction.
7. (Original) The method of claim 1 wherein the liquid is formed by mixture with water.
8. (Original) The method of claim 1 wherein the liquid is formed by mixture with organic solvent.
9. (Original) The method of claim 1, further comprising adding a capping agent to the elemental nanoparticles, wherein the capping agent selected from the group of phosphines, amines, alcohols, thiols, ethers, water and glycols, trioctylphosphine oxide, trioctylphosphine, triphenylphosphine, pyridine, methanol, ethanol, propanol, butanol, ethane thiol, tetrahydrofuran, ethers, ammonia, methyl amine, ethylamine, ethylenediamine, and acetonitrile.
10. (Original) The method of claim 1, further comprising adding a binder to the elemental nanoparticles.
11. (Original) The method of claim 1, further comprising adding a fluxing agent to the elemental nanoparticles.
12. (Original) The method of claim 1, further comprising adding one or more surfactants, polymers, dispersants, binders, modifiers, detergents or additives to the elemental nanoparticles.

13. (Currently Amended) A method for fabricating a liquid containing intermixed elements of groups IB and IIIA, and optionally VIA, comprising the steps of:
forming non-oxide quantum nanoparticles containing elements from group IB; and—forming non-oxide quantum nanoparticles containing elements from group IIIA; and optionally forming non-oxide quantum nanoparticles containing elements from group VIA;
providing a suspension comprised of one or more liquid metals, wherein the one or more liquid metals comprises at least one group IIIA based material;
intermixing the non-oxide quantum nanoparticles from groups IB and IIIA and optionally VIA, with the suspension to form an ink;

wherein the non-oxide quantum nanoparticles are in a desired particle size range of between about 0.1 nm and about 10 nm in diameter, wherein, for each element, a majority of the mass of the non-oxide quantum nanoparticles range in size from no more than about 40% above or below an average particle size, or, if the average particle size is less than about 5 nanometers, from no more than about 2 nanometers above or below the average particle size ~~;~~**and**
mixing the non-oxide nanoparticles to form a liquid that serves as an ink.

14. (Original) The method of claim 13 wherein the non-oxide quantum nanoparticles are quantum dots, quantum wires, quantum wells, or quantum rods.

15. (Original) The method of claim 13 wherein the group IB element is copper (Cu), the group IIIA element is indium and optionally includes gallium) and the group VIA element is selenium (Se) or sulfur (S) and a stoichiometric ratio of the Cu, In and Se or S in the liquid is approximately $\text{CuIn}_{1-x}\text{Ga}_x(\text{S or Se})_2$, where x is between 0 and 1.

16. (Canceled)

17. (Canceled)

18. (Original) The method of claim 13 wherein the ligand/capping agent is selected from the group of phosphines, amines, alcohols, thiols, ethers, water and glycols, trioctylphosphine oxide, trioctylphosphine, triphenylphosphine, pyridine, methanol, ethanol, propanol, butanol, ethane thiol, tetrahydrofuran, ethers, ammonia, methyl amine, ethylamine, ethylenediamine, and acetonitrile.

19. (Canceled)

20. (Canceled)

21. (Original) The method of claim 13 wherein forming a mixture of non-oxide quantum nanoparticles includes spray co-precipitation of two or more reactants.

22. (Original) The method of claim 21 wherein one of the two or more reactants is selected from the group of metal halides, metal acetates, metal sulfates, metal nitrates, metal alcholates, metal carbonates, metal phenolates, metal hydroxides, and organometallics.
23. (Original) The method of claim 22 wherein the two or more reactants include one or more reactants of the type X/Hal, where X is Cu or In and Hal is chlorine (Cl) or iodine (I).
24. (Original) The method of claim 23 wherein the two or more reactants further include thiourea or selenourea.
25. (Original) The method of claim 13 wherein forming a mixture of non-oxide quantum nanoparticles includes performing a reaction of the type:
$$(IB)(Et_2CN(VIA)_2)_2 + TOPO \rightarrow IB\text{-}VIA$$
26. (Original) The method of claim 25 wherein IB is Cu and VIA is Se or S.
27. (Original) The method of claim 13 wherein forming a mixture of non-oxide quantum nanoparticles includes performing a reaction of the type:
$$(IB)(Hal) + Na_2(VIA) + \text{ligand/capping agent} \rightarrow IB\text{-}VIA + 2Na(Hal)$$
28. (Original) The method of claim 27 wherein the ligand/capping agent is selected from the group of trioctylphosphine oxide, trioctylphosphine, triphenylphosphine, pyridine, alcohols (methanol, ethanol, propanol, butanol), ethane thiol, tetrahydrofuran, ethers, ammonia, amines (methyl amine, ethylamine, ethylenediamine) and acetonitrile.
29. (Original) The method of claim 27 wherein the reaction is of the type:
$$CuCl_2 + Na_2Se + \text{Pyridine} \rightarrow CuSe + 2NaI.$$
30. (Canceled)
31. (Canceled)

32. (Currently Amended) The method of claim 13 wherein forming a mixture of non-oxide quantum nanoparticles includes sonochemical synthesis of nanoparticles particles ~~containing Se with Cu or In or Ga.~~

33. (Currently Amended) The method of claim 13 wherein forming non-oxide quantum nanoparticles includes preparing metal nanoparticles ~~containing elements of groups IB, IIIA, VIA or a IB-IIIA-VIA alloy~~, by laser ablation, nucleation from vapor, exploding wires by electrical current surge, thermal decomposition of organometallic compounds, sonolysis, pulse radiolysis, electrochemical reduction or chemical reduction.

34. (Original) The method of claim 13 wherein the liquid is formed by mixture with water.

35. (Original) The method of claim 13 wherein the liquid is formed by mixture with organic solvent.

36. (Original) The method of claim 13, further comprising adding a capping agent to the non-oxide quantum nanoparticles.

37. (Original) The method of claim 13, further comprising adding a binder to the non-oxide quantum nanoparticles.

38. (Original) The method of claim 13, further comprising adding a fluxing agent to the non-oxide quantum nanoparticles.

39. (Original) The method of claim 13, further comprising adding one or more surfactants, polymers, dispersants, binders, modifiers, detergents or additives to the non-oxide quantum nanoparticles.

40. (Currently Amended) A method for fabricating a liquid containing intermixed elements of groups IB and IIIA and optionally VIA, comprising ~~the steps of:~~

forming nanoparticles from group IB; and

intermixing the nanoparticles from group IB with one or more elements from group IIIA in a suspension to form an ink, wherein the one or more elements from group IIIA are in molten form;

[,] wherein the nanoparticles from group IB comprise particles in a desired particle size range of between about 0.1 nm and about 500 nm in diameter, wherein a majority of the mass of the nanoparticles range in size from no more than about 40% above or below an average particle

size, or, if the average particle size is less than about 5 nanometers, from no more than about 2 nanometers above or below the average particle size; **and**

mixing the nanoparticles with the molten elements to form a liquid that serves as an ink.

41. (Original) The method of claim 40 wherein the group IB element is copper (Cu), the group IIIA element is indium and optionally includes gallium) and the group VIA element is selenium (Se) or sulfur (S) and a stoichiometric ratio of the Cu, In and Se or S in the liquid is approximately $CuIn_{1-x}Ga_x(S \text{ or } Se)_2$, where x is between 0 and 1.

42. (Original) The method of claim 41 wherein a majority of the group IB nanoparticles range in size from no more than about 40% above or below an average nanoparticle size, or, if the average nanoparticle size is less than about 5 nanometers, from no more than about 2 nanometers above or below the average nanoparticle size.

43. (Original) The method of claim 40, further comprising adjusting the temperature of the Cu-In-Ga mixture until a solid forms and then grinding the solid to form nanoparticles.

44. (Original) The method of claims 1, 13, or 40 further comprising the step of capping the nanoparticles with an organic material.

45. (Original) The method of claim 44 wherein the organic material is a small molecule with low boiling point.

46. (Original) The method of claim 44 wherein the organic material is selected from the group of trioctylphosphine oxide, trioctylphosphine, triphenylphosphine, pyridine, alcohols (methanol, ethanol, propanol, butanol), ethane thiol, tetrahydrofuran, ethers, ammonia, amines (methyl amine, ethylamine, ethylenediamine) and acetonitrile.

47. (Original) The method of claims 44 wherein the organic material is pyridine.

48. (Original) The method of claim 1, 13, or 40 wherein forming a mixture of non-oxide nanoparticles includes selecting particles in the desired particle size range.

49. (Original) The method of claim 48, wherein selecting nanoparticles in the desired size range includes adjusting one or more parameters of a reaction that forms the nanoparticles, size-selective precipitation, or ultrafiltration.

50. (Original) The method of claims 1, 13 or 40 further comprising adding a water-compatible dispersant to the liquid.

51. (Original) The method of claims 1, 13, or 40 wherein forming the non-oxide nanoparticles includes preparing particles in a non-oxygen atmosphere.

52. Canceled.

53. Canceled.

54. Canceled.

55. Canceled.

56. Canceled.

57. Canceled.

58. Canceled.

59. Canceled.

60. Canceled.

61. (Currently Amended) A method for fabricating a photovoltaic cell active layer containing a IB-IIIA-VIA alloy, comprising ~~the steps of:~~

forming a liquid ink containing ~~intermixed nanoparticles of~~ elements from groups IB, IIIA and optionally VIA, using the method of claim 1, 13, 40 or 75;

spreading a film of the liquid onto a substrate;

annealing the film ~~to form the active layer~~; and

exposing the film to Se-containing vapor.

62. (Original) The method of claim 61, wherein the IB-IIIA-VIA alloy is an alloy of copper (Cu) with indium (In) or Gallium (Ga) and selenium (Se) or sulfur (S) having a stoichiometric ratio of the Cu, In and Se or S of approximately CuIn_{1-x}Ga_x(S or Se)2, wherein x is between 0 and 1.

63. (Original) The method of claim 61 wherein the substrate is a polymer or metallized polymer.

64. (Original) The method of claim 61, wherein annealing the film includes heating the film to a temperature between about 200°C and about 600°C.

65. (Original) The method of claim 61, wherein the film is spread onto the substrate and/or annealed in a roll-to-roll production system.

66. (Currently Amended) The method of claim 61, further comprising, winding the substrate into a coil, wherein the exposing the film to Se-containing vapor comprises and exposing the coiled substrate to selenium vapor.

67. (Original) The method of claim 61 wherein annealing the substrate includes winding the substrate into a coil and heating the coiled substrate.

68. (Original) The method of claim 61, further comprising winding the substrate into a coil and depositing a layer of material on one or more surfaces of the coiled substrate.

69. (Currently Amended) The method of claim 681 wherein the layer of material includes a transparent conductive oxide.

70. (Original) The method of claim 61 wherein forming the liquid, spreading the film of the liquid and annealing the film does not include the use of H₂Se to selenize the particles, film or active layer.

71. (Original) The method of claim 61 wherein forming the liquid, spreading the film of the liquid and annealing the film does not include reduction of the particles, film or active layer with H₂.

72. (Canceled)

73. (Canceled)

74. (Canceled)

75. (Currently Amended) A method comprising:

providing a suspension comprised of one or more liquid metals, wherein the one or more liquid metals comprises ~~of~~ at least one group IIIA based material;

providing a plurality of nanoparticles, wherein the nanoparticles comprise ~~of~~ at least one group IB based material; and
mixing the nanoparticles and the suspension to form an ink configured to be processed in one or more steps into a photovoltaic absorber layer.

76. (Previously Presented) The method of claim 75 wherein the suspension comprises a first liquid and a second liquid, wherein the first liquid comprises the one or more liquid metals.

77. (Previously Presented) The method of claim 76 wherein the second liquid comprises a solvent.

78. (Previously Presented) The method of claim 76 wherein the second liquid comprises an organic solvent.

79. (Currently Amended) The method of claim 76 wherein the first liquid in the suspension is not miscible with the second liquid.

80. (Previously Presented) The method of claim 75 wherein the suspension comprises a mixture of two or more immiscible liquids wherein one liquid comprises one or more liquid metals dispersed in the other liquid.

81. (Previously Presented) The method of claim 75 wherein the suspension comprises an emulsion of one or more liquid metals in at least one carrier liquid.

82. (Previously Presented) The method of claim 75 wherein the one or more liquid metals comprises of a molten mixture of Gallium and/or Indium.

83. (Previously Presented) The method of claim 75 wherein the nanoparticles are elemental nanoparticles.

84. (Previously Presented) The method of claim 75 wherein the nanoparticles are binary alloy nanoparticles.